

display of forces at the sun's surface. In this respect the theory will be submitted to an exhaustive test in my paper in the *Annals*. In one important point it involves a radical deviation from the views hitherto held. So far investigators have almost unanimously adhered to the traditional view that an increase in the dynamical forces at the sun's surface indicates at the same time an augmentation of his light- and heat-radiation into the universe. A theory founded on this assumption would have to account, not only for the extra expenditure of force into space, but also for the simultaneous increased development of force in the sun. But in the theory here proposed the exactly opposite conclusion is arrived at. Here the forces which we see acting on the sun are called into existence by the accumulation of such parts of his radiating energy as have been prevented from being thrown off into the universe. Thus a surplus of energy working on the sun means a deficit of energy communicated to space.

It will be important, then, to ascertain how far this conclusion can be verified by observed facts. Modern researches seem, indeed, to corroborate this theoretical result. If the theory be true, the temperature of the solar layers inside the absorbing atmosphere should be higher at the maxima than at the minima of solar activity, while the temperature of a body in space, which receives its heat from the sun, should vary inversely. In proof of the first conclusion I may refer to Sir Norman Lockyer's results with regard to the be-

Behrens divides the bronzes into two principal groups—those rich in copper, containing from 1 to 25 per cent. of tin, and those rich in tin, containing more than 25 per cent. of tin. With the exception of the metals for mirrors (25 to 35 per cent. of tin), which appear homogeneous, Mr. Behrens says that in all bronzes a portion rich in copper or rich in tin may be detected, forming the fundamental mass, the former in alloys rich in copper, the latter in those rich in tin.

Charpy (*Metallographist*, vol. i. p. 193) divides them into those rich in copper, containing 100 to 73 per cent. of copper, and those rich in tin, which are again divided into four groups—0 to 3 per cent. of copper, in which tin crystallises in the matrix; 3 to 55 per cent. of copper, in which a compound of tin and copper crystallises out of the matrix; 55 to 65 per cent. of copper, which have a structure quite homogeneous and difficult to resolve; and 65 to 73 per cent. of copper, in which hard white grains crystallise in the higher eutectic.

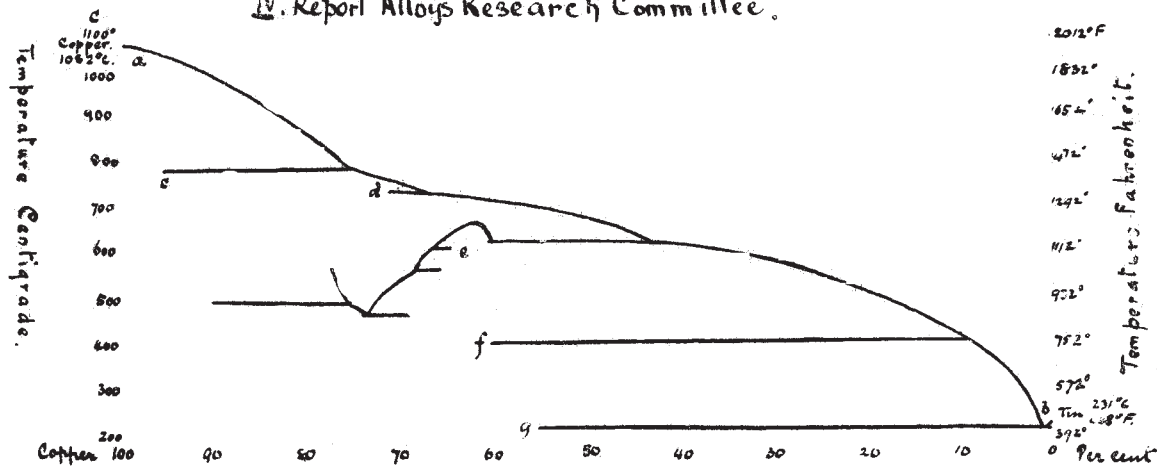
The curve of fusibility, as determined by Le Chatelier, is composed of three branches, forming by their intersections two points corresponding to alloys with 3 and 72 per cent. of copper.

0 to 3 per cent. of copper : straight : fall.
3 to 72 „ „ uniformly curved : rise.
72 to 100 „ „ almost straight : rise.

This curve and the results of Charpy (*Bull. Soc. d'Encouragement*, March, 1897) from microscopic analysis closely agree.

Fig. 1. Freezing-point Curve of Copper-Tin Alloys.

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haviour of the lines widened in the spectra of sunspots, from which he infers that the matter composing the spots must be of higher temperature at the times of maxima. The second conclusion, on the other hand, is corroborated by all the more important researches which have recently been made regarding a connection between the changes of terrestrial temperature and solar activity. Of some of these I subjoin the main results in Fig. 2, which exhibits the observed changes in the mean annual temperature at tropical and subtropical stations and the corresponding variations of solar activity. It will be seen that for the whole period from 1821 until 1898 the temperature-curve follows most accurately the fluctuations of the inverted spot-curve, thus so far proving the validity of the second conclusion, that space receives less heat at the maxima than at the minima of solar activity.

J. HALM.

MICROSCOPICAL EXAMINATION OF ALLOYS OF COPPER AND TIN.¹

THE microstructure of the copper-tin alloys has been studied by Behrens, Charpy, Stead and others. Recently Messrs. Heycock and Neville (*Phil. Trans. Royal Society*, 1901; Glasgow meeting, British Association) have published several papers on the effect of quenching upon the microstructure.

¹ Abstract of a paper by Mr. William Campbell, Columbia University, New York, late of the Royal School of Mines, London. Read before the Institution of Mechanical Engineers on December 20, 1901.

If, however, we study the complete cooling curve of the copper-tin alloys, by Sir William Roberts-Austen (Fig. 1), the meaning of only a part of the curve will be found to have been explained by previous workers. The branches c, d, e and f remain unaccounted for.

The result of the microscopical study of these alloys is shortly as follows:—

0 to 1 per cent. Copper.—On the addition of even 0.1 per cent. of copper to tin, a new constituent surrounding the grains of tin can be seen. As the percentage of copper increases, the amount of enveloping material increases also, and the tin grains decrease in size and number until about 1 per cent. copper; they entirely disappear when the whole mass is composed of the first eutectic alloy. When these alloys are cast, the grains of tin are greatly reduced in size.

1 to 8 per cent. Copper.—When the copper is increased above 1 per cent., thin bright needles are seen, which increase in size and number and vary in their method of grouping until 8 per cent. of copper is reached. Their composition varies also, increasing from 33.5 per cent. Cu to 44 per cent. Cu, as was pointed out by Stead (*Journal of the Society of Chemical Industry*, June, 1897). Casting produces a network of fine crystallites, which tend to set along definite directions forming skeleton crystals. Cooling in the furnace greatly increases the size of the bright crystals and diminishes their number proportionately.

9 to 40 per cent. Copper.—With 9 per cent. Cu a new constituent crystallises out in forms similar in section to the crystals

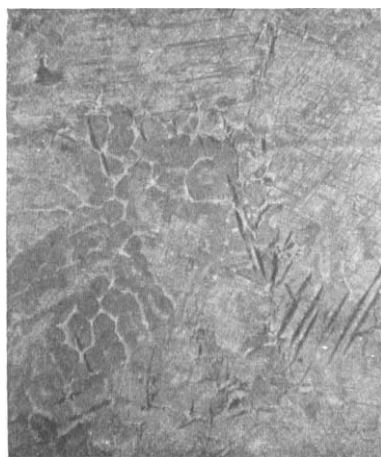


FIG. 2.—Cu 66 per cent. $\times 33$. V.

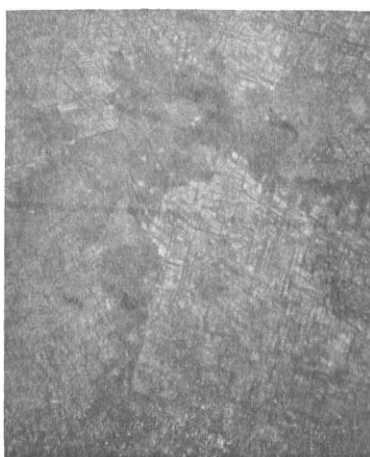


FIG. 3.—Cu 66 per cent. $\times 33$. V.

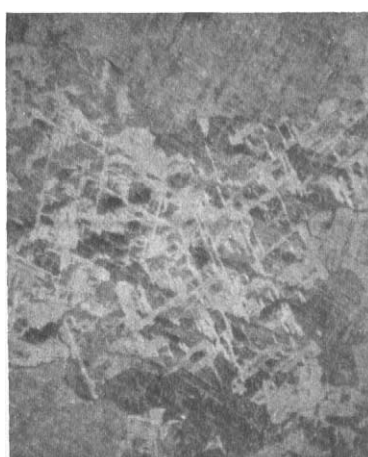


FIG. 4.—Cu 66 per cent. $\times 33$. V.

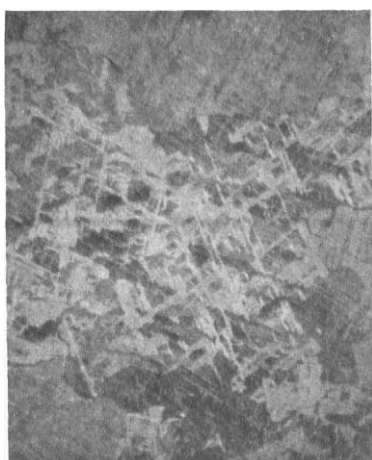


FIG. 5.—Cu 66 per cent. $\times 33$. V.

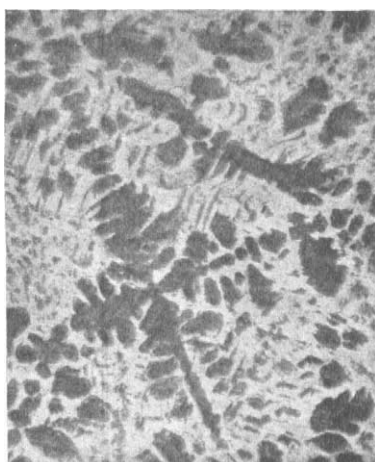


FIG. 6.—Cu 80 per cent., furnace-cooled, $\times 33$. V.



FIG. 7.—Surface of Fig. 6.



FIG. 8.—Cu 80 per cent. $\times 33$. V.

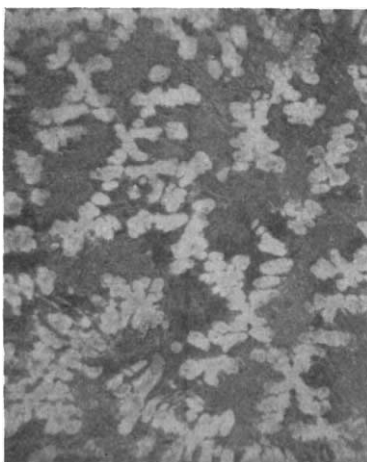


FIG. 9.—Cu 80 per cent. $\times 33$. V

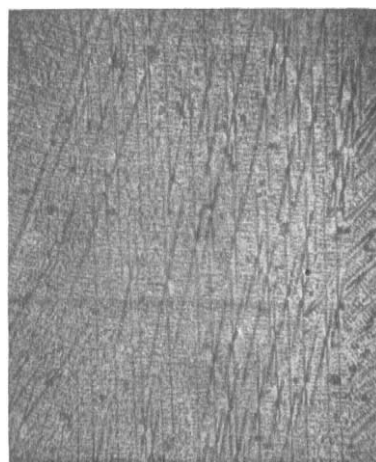


FIG. 10.—Cu 80 per cent., cast, $\times 33$. V

V, vertical illumination.

in the 1 to 8 per cent. alloys, but differing from them in never occurring hollow. On oxidation it becomes very dark and is easily distinguished from the other two constituents of the alloy. In form it is plate-like, and around it crystallises out the bright constituent characteristic of the 1 to 8 per cent. alloys, either as a rough envelope of fairly uniform thickness or as projecting crystals. Stead was the first to draw attention to the fact that the crystals of this division of the series were composite. As the copper approaches 40 per cent., the plate-like crystals are grouped together in parallel bunches. Casting masks the composite character of the crystals, if, in the lower percentages, it does not destroy it; for under 20 per cent. Cu, the crystals cannot be resolved into two components under high powers.

41 to 61·7 per cent. Copper.—At 41 per cent. Cu the crystals are small, lath-shaped, and arranged more or less in groups. The alloy is brittle, and this brittleness increases with the percentage of copper. With each addition of copper, the groups of composite crystals become more and more compact and the amount of eutectic diminishes until at 56 per cent. Cu it disappears (Stead, *Journal of the Society of Chemical Industry*, June, 1897), and the bright constituent of the crystals forms the groundmass. When 61·7 per cent. Cu is reached, the bright constituent disappears and we have a homogeneous mass of SnCu_3 , probably a definite compound. Casting tends to harden and toughen these alloys. Seeing that these alloys up to about 56 per cent. Cu show four breaks in their cooling curves, one would naturally expect to find four different constituents in each. Only three, however, can be distinguished. Quenching below the first and second breaks gives a difference in structure only. As in the alloys containing 61·7 per cent. Cu and onwards, branch *e* of the curve (Fig. 1) corresponds to a rearrangement in the solid, and as the difference between the 40 and 41 per cent. Cu alloys is one of structure only, we may assume that the second retardation in the cooling curve (*e*) is one of rearrangement also.

61·7 to 68·28 per cent. Copper, SnCu_3 to SnCu_4 .—The changes which take place between these two points can only be observed when the alloys are very slowly cooled. The alloys set as a whole at the first break and tend to rearrange themselves subsequently in the solid, on branch *e* (Fig. 1). Each addition of copper to SnCu_3 brings in more and more of a bright constituent, probably SnCu_4 . Quenching and casting produces structures entirely new. Figs. 2-5 show the 66 per cent. Cu alloy differently cooled. Fig. 2 was quenched on the first break. There is a cell-like structure with light-coloured walls or boundaries. In places the change has gone further, and we get the fine cross-hatching characteristic of Fig. 3, which has been quenched below the first break. The cell-like structure has entirely disappeared. Fig. 4 has been quenched below the second break and resembles a slowly-cooled alloy, except that in the latter there are distinct traces of a eutectic structure. Fig. 5 has been cast on an iron plate, and the "schiller" structure is well developed. At 68·2 per cent. Cu the alloy is homogeneous, has a conchoidal fracture and is extremely brittle.

68·28 to 75 per cent. Copper.—Immediately the copper is increased above 68·3 per cent., the second eutectic makes its appearance. As the copper increases, the grains of SnCu_4 split up into bright veins and dendrites, surrounded by the eutectic. The veins and dendrites decrease and disappear at 75 per cent. Cu, where the mass is made up entirely of the eutectic. The alloys are best studied when furnace-cooled; their surfaces above 71 per cent. Cu are seen to consist of a network of dendrites or skeleton crystals resembling those seen on the surface of a pure metal. This surface structure continues right up to the copper end of the series. It was soon noticed that the internal structure of the alloys from 70 to 75 per cent. Cu showed no trace of these dendrites, and so the surfaces of several were rubbed down and polished. In each case their structure was the same as that of the centre of the alloy, which shows that these dendrites have split up and rearranged themselves after solidification, and all that remains of them is this surface structure. Casting makes the structure very minute, and about 73 per cent. Cu traces of the skeleton crystals can be seen in the centre of the ingot. They appear dark and structureless, as if they had been unable to resolve themselves into their two constituents.

75 to 100 per cent. Copper.—When 76 per cent. copper is present, two new constituents make their appearance and the alloy assumes a yellow tint. In section we find yellow grains, surrounded by a bright white border, set in the second eutectic,

in which small bright white grains also occur. As the total copper is increased, the yellow grains increase, forming dendrites and skeleton crystals, the white borders and grains merge together and the eutectic decreases till at about 90 per cent. it disappears. The yellow grains become darker and darker (contain less and less tin in solid solution). The light borders diminish and disappear, about 95 per cent. leaving copper dendrites behind. These dendrites vary in composition from centre to outside, and so the centre etches a darker colour. They darken with increase of copper until 100 per cent. is reached. Casting tends to make the copper grains solidify, containing a considerable quantity of tin. In this way the eutectic can be made to disappear considerably below 90 per cent. Cu. Quenching shows that the upper break corresponds to the solidification of the copper; break 2 to the solidification of the groundmass which splits up into a eutectic when branch *e* is reached. Fig. 6 contains 80 per cent. Cu furnace-cooled, whilst Fig. 7 shows the surface of the same and also that with this percentage of copper the dendrites of copper have directed the formation of the surface skeletons. Fig. 8 is the same alloy quenched below first break. The dendrites of copper are seen set in a structureless matrix. Fig. 9 is the same alloy quenched below the second break. The dendrites of copper (light, because of a different etching process) are seen, set in a fibrous matrix—the eutectic of which the formation has been faced. Fig. 10 shows the same alloy cast. As its appearance would indicate, the alloy is very tough and cuts well.

It seems clear then that branch *e* of the cooling curve is one of change in the solid, and this conclusion has been proved beyond doubt by the beautiful work of Heycock and Neville published by the Royal Society. When one considers the many and distinct different structures in the series produced by quenching at different temperatures and by reheating and then quenching, it is quite evident that the changes which take place during the cooling of an alloy of copper and tin, especially in the neighbourhood of the second eutectic, are even more numerous than those of the carbon-irons.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

CAMBRIDGE.—The Allen studentship, value 250*l.* for one year, for research in connection with medicine, mathematics, physics and chemistry, biology and geology, or moral science, will be filled up at the end of the present term. It is open to graduates under the age of twenty-eight on January 8.

Principal E. H. Griffiths, F.R.S., of Cardiff University College, has been approved for the degree of Doctor of Science.

The Rede lecture will be delivered next term by Prof. Osborne Reynolds, F.R.S., of Owens College, Manchester.

Mr. W. N. Shaw, F.R.S., will give three lectures, on February 13, 20 and 27, on the physics of the ventilation of buildings.

Prof. Tilden, F.R.S., has been appointed an elector to the chair of chemistry; Lord Rayleigh, F.R.S., an elector to the chairs of chemistry and of mechanism; Dr. Hill, to the anatomy chair; Mr. F. Darwin, F.R.S., to the botany chair; Dr. Hinde, F.R.S., to the geology chair (Woodwardian); Sir G. G. Stokes, F.R.S., to the Jacksonian and Cavendish chairs; Dr. D. MacAlister, to the Downing chair of medicine; Dr. Hugo Müller, F.R.S., to the chair of mineralogy; Prof. E. Ray Lankester, F.R.S., to the chair of zoology and comparative anatomy; Prof. McKendrick, F.R.S., to the chair of physiology; Lord Lister, F.R.S., to the chair of pathology; and Prof. Marshall Ward, F.R.S., to the chair of agriculture.

Dr. J. Reynolds Green, F.R.S., has been elected to a fellowship at Downing College.

THE University College, Bristol, does not receive the generous support given to similar colleges elsewhere, but the report of the council for the session 1900-01 shows that much valuable work has been done in spite of limited means and opportunities. Important papers have been published by various members of the scientific staff and others are in progress. The clinical and bacteriological research laboratory, which has been, at work under Prof. Stanley Kent for little more than a year, has, among other matters, been able to afford valuable aid to the Medical Officer of Health in reporting upon the presence of plague in-